The "Know-How" Tradition: Technology in American History

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THE EMERGENCE of the History of Technology as a discipline in its own right is an event to be hailed by all those who believe that the role of technology in the story of mankind needs more thorough study and more careful evaluation than it has so far received. It also provides an appropriate opportunity to consider the relationship of this subject to other areas of history. There is a great deal of valuable work being done and still to be done in the History of Technology *per se*. No field of history, however, can usefully be dealt with in isolation; unless it is related to the whole current of historical change, it is likely to deteriorate into futile scholasticism.

Having thus taken a firm stand for the "seamless web" concept of history I now propose to tear the web apart and deal with only a portion of it:—to wit, the portion comprising the history of the United States. For one thing, this is the area I know most about; for another, American society has been influenced to a unique degree by the forces of technology.

As a people we have given ample lip service to technology. Until a year or so ago it was an article of faith that Americans had an ingrained superiority in technical "know-how," and if we have lost a little of our self-confidence, it has been only a little. We have a completely justified pride in the achievement of American civilization in applying technology to the material advancement of

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its people, although our pride in this achievement has not been matched by understanding of how it came about. For many Americans, information on the growth of their country's technology is about on the level of the conversation in a Pullman smoking room which Frederick L. Smith, one-time president of the Olds Motor Works, reported overhearing in the 1920's.[1]

"Who invented the automobile anyway?"

"Henry Ford. Started as a racer by beating Barney Oldfield on the ice at Detroit. Right away after that he built a plant to turn out the same kind of car in 50,000 lots."

"Doesn't he own the Lincoln now?"

"Yeah, owns the Lincoln and the Packard, Cadillac, Buick—all the big ones and a lot of the little ones besides."

"Is it true about his taking over the Detroit City Hospital?"

"I'll say it's true. Bought it and runs it for his employees. Charges everybody a fixed rate for every job and makes it pay."

I wish to suggest here that a clearer and more complete knowledge of the role of technology in American history is not merely desirable but necessary to a full understanding of the evolution of American civilization. In particular, unless adequate weight is given to the technological factor, it is completely impossible to give an accurate picture of the growth and character of American business enterprise.

Before we go any further, we should perhaps try to define what we mean by technology. It is not easy to do so. Technology includes engineering, but the two are not synonymous, and no one who is concerned with curricular problems in present-day engineering colleges is likely to be bold enough to attempt to explain exactly where technology stops and science begins. I like the definition of engineering formulated by President R. E. Doherty of the Carnegie Institute of Technology:

"Engineering is the art, based primarily upon training in mathematical and physical sciences, of utilizing economically the forces and materials of nature for the benefit of man."[2]

Technology may be regarded as comprehending trial-and-error and rule-of-thumb as well as the systematic application of scientific principles, which brings us close enough for practical purposes to the definition given by V. Gordon Childe in Singer's *History of Technology:*

"Technology should mean the study of those activities, directed to the satisfaction of human needs, which produce alterations in the material world." [3]

The technological aspect of American history comes to us mostly in unrelated fragments—the principal inventors and inventions, with at best casual reference to the circumstances which stimulated them; something of early industrial development, emphasizing its political repercussions; railroad expansion, generally in terms of the organization of large systems; the growth of big business, again with political overtones.

To cite one conspicuous example, every student of American history learns about the economic importance of the Erie Canal, but reference to the fact that the canal was a monumental engineering achievement is likely to be incidental. It would not detract from the credit to which DeWitt Clinton is rightfully entitled if we recognized the work of Benjamin Wright and Canvass White or pointed out that the Erie Canal was the training school for a substantial group of brilliant civil engineers.

However, merely enlarging the bits and pieces is not enough. A society which has been as profoundly influenced by technology as ours needs to be able to see how technology has been woven into the fabric of its national life. I do not propose to accomplish that in this paper. Even if space permitted, I do not possess any such encyclopedic information. All I can do is point out some of the factors which I consider to be of major importance.

The first of these is the overwhelmingly pragmatic character of American technology. It is most appropriate that our favorite synonym for technical skill should be "know-how," because as a people we have placed a far higher premium on knowing how than on knowing why. The folk-heroes of American technology are the Edisons and the Fords, men with a minimum of formal training, dedicated to cut-and-try, lacking in scientific background, and inclined to be scornful of scientific method. Until well into the 20th century, Americans have been content to let most of the basic discoveries in science and technology originate in Europe while they themselves have followed a policy of "adapt, improve, and apply."

The reason for this phenomenon is obvious enough. The United States began as an undeveloped area, without benefit of a fairy

godmother distributing largesse in the form of economic aid or technical assistance. There was chronically more work to be done than there were people to do it, so that labor, particularly skilled labor, was likely to be in short supply and expensive. Securing trained ironworkers for the ironworks at Saugus, Massachusetts, in the 1640's was one of the company's most difficult problems,[4] and a century and a half later the high cost of craftsmen in the United States was a primary factor in stimulating Eli Whitney and Simeon North to turn their attention to the manufacture of firearms by a method which would permit the substitution of mechanical for human skill.[5] Similarly, while machine production of textiles began in the United States later than in Great Britain, the American industry mechanized more rapidly because of the need to employ techniques in which skill would be a minor factor.[6] For example, although Cartwright's power loom appeared in England in the 1780's, a good half century elapsed before mechanized weaving displaced the crafts technique in the British textile industry, in part because the power loom needed considerable refinement before it could compete in quality with the work of the hand weaver. As a result, the weaving process in Great Britain was generally organized separately from the other operations of textile manufacturing. On the other hand, when Francis Cabot Lowell designed his power loom in 1813, he and his associates developed it into a large-scale business enterprise in a little more than ten years. In characteristic fashion, cotton manufacturing by the "Lowell system" was organized on an integrated basis, with all the operations conducted in a single factory, a maximum of mechanization, and even a labor policy devised to meet the conditions of early nineteenth century New England.[7]

American conditions, in other words, placed a high valuation on getting things done, preferably in the shortest possible time and with the minimum of human labor. The man who could devise a gadget or a technique which would work was making a recognizable contribution to the growth of the country, whether he understood the fundamental principles he was using or not. One consequence was that to the end of the 19th century the relationship between science and technology in the United States was somewhat casual. Where science had a practical application, it was invoked. The invention of the telegraph depended heavily on Joseph

Henry's research in magnetism—Morse, indeed, could hardly have succeeded without Henry's assistance—and George H. Bissell invoked the skill of Benjamin Silliman, Jr., the leading American chemist of his day, for an evaluation of the commercial possibilities of petroleum when the Pennsylvania oil fields began to attract attention. These contacts, however, were spasmodic and rare. There was little interest in accumulating scientific knowledge as a foundation for future technological advance and still less in accumulating such knowledge for its own sake. It was completely in accord with the pattern of American thought that when Congress undertook to promote higher technical education by the Morrill Act of 1862, it singled out agriculture and the mechanic arts as the areas to be given particular attention.

This attitude has been subjected to substantial modification as our technology has become increasingly complex and increasingly dependent on science. Nevertheless, the emphasis on the practical still dominates American thinking, and its existence has to be recognized if we are to evaluate properly the place of technology in American history. Moreover, while we can concede that we have unduly neglected "pure" or "basic" research in the past and now need to give it more vigorous encouragement, it does not follow that the American emphasis on the practical has been wrong. It was determined in the first place by circumstances; beyond that, if we recall our definition that technology is an activity directed to the satisfaction of human needs, then American technology has been performing its function with phenomenal success. "Adapt, improve, and apply" may have less glamour than original creativity, but the technique of application may in itself be more significantly creative than the original idea or invention. In the reminiscences from which the story on Henry Ford came, the author also remarked—this in the late 1920's—that since Karl Benz introduced spark ignition in 1886, nothing has been added to the gasoline automobile but the assembling of known parts.[8] Maybe so—but what has happened to the process of assembly, and the economic and social consequences thereof, makes quite a story. Nor does it follow that the pragmatic approach necessarily precludes research in fundamentals. Kendall Birr's scholarly study of the General Electric Research Laboratory

makes it clear that a good deal of "basic" research grew out of efforts to find a solution to a specific problem.[9]

The second major factor which could profitably be given more attention is the interrelationship between technological development and industrial application. While some work has been done on the problem of invention and innovation, this whole area needs more intensive research in order to untangle some of its complex of causes and effects. Technological change may and frequently does originate in an isolated act of genius, but its effectiveness in an economic sense is a matter of time and circumstances. A classic American illustration is George B. Selden's patent on a motor vehicle powered by an internal combustion engine, for which he filed his application in 1879. This story cannot be told in detail here. It is sufficient to point out that Selden had worked out the essential technical features of the gasoline automobile but that he was unable to exploit his idea because he was ahead of his time. The highway system of the United States was totally inadequate to the demands of travel by motor vehicle: as late as 1900 there was not enough paved road outside the big cities to make a continuous route from New York to Boston [10]—a matter of just over 200 miles. Moreover, considerable development in manufacturing techniques and machine tools was needed before a practical automobile could be successfully put into commercial production. So Selden, who might have been the father of the American automobile industry, became instead an obscure figure in an elaborate and much misunderstood lawsuit.

The story of aluminum offers an even clearer illustration. The properties of the metal were known and some experimental work had been done in reducing aluminum ore before Charles Martin Hall and Paul L. T. Heroult independently and almost simultaneously discovered the electrolytic process.[11] There had even been experiments with electrolysis, but a practical method of producing aluminum at a cost low enough to remove it from the list of precious metals had to wait for Charles S. Bradley's electric furnace, patented in 1885,[12] and that in turn depended on the development of a dynamo capable of generating electric power in large quantities. Here indeed is an excellent example of the distinction between science and technology. Hans Christian Oersted isolated aluminum in his laboratory in 1825; industrial utilization had to

wait for over sixty years and the development of other separate technologies.

My final point in this paper is that we must give more attention to the role of technology in the growth and organization of industry. Our failure to do so in the past has resulted in misconceptions and distortions, particularly in the area of big business. Despite the very substantial amount of work which has been done in reappraising business and business men, the predominant attitude is still suspicion of bigness. We may acknowledge that large-scale organization has advantages in economy and efficiency of operation, but in our hearts we continue to take it for granted that the creators of these organizations invariably had conscious monopolistic intent or wished to manipulate security issues. We seldom inquire into the possible relationship between the growth and structure of the business and the technological processes in which it was engaged.

It is not merely a question of reinterpreting past events in the light of new information. Much of the information has been available all along and has simply been disregarded. As a prime illustration, let me go back to the old familiar story of the Standard Oil Company. I have no intention of rewriting this story or of suggesting that railroad rate rebates no longer form part of the record—although I could argue that they have been badly overworked. I simply wish to point out certain features which do not appear in the conventional picture handed down from the era of Henry D. Lloyd and Ida M. Tarbell.

Historians agree that John D. Rockefeller owed much to his strategic position as the leading refiner in Cleveland—but how did he get to be the leading refiner in Cleveland? Lloyd sees a deep-seated, nefarious plot here, saying, "He (Rockefeller) started a little refinery in Cleveland, hundreds of miles from the oil wells." [13] Since the distance from Cleveland to Oil City, Pennsylvania, is about 115 miles, and to Titusville only a little more, one might question the author's standard of accuracy, but this is perhaps a digression. In the same passage Lloyd goes on to say: "With him were his brother and an English mechanic. The mechanic was bought out later, as all the expert skill needed could be bought for wages, which were cheaper than dividends."

Now this "English mechanic" whom Lloyd dismisses so cava-

lierly was none other than Samuel Andrews, a Rockefeller partner for fifteen years and a key figure in the early history of Standard Oil. He is described by Ida M. Tarbell as "a mechanical genius. He devised new processes, made a better quality of oil, got larger and larger percentages of refined from his crude," [14] and by Allan Nevins as "the best superintending refiner in Cleveland." [15] Miss Tarbell is a little more lyrical; Dr. Nevins, on the other hand, makes the essential point that Rockefeller's success was in no small part due to his ability to select gifted associates. In this case, Rockefeller seems entitled to full credit not only for appreciating Andrews' skill but also for recognizing at the outset the necessity for being technically superior to his competitors.

Miss Tarbell's acknowledgment of Andrews' merits does not extend to approval of Rockefeller and his company. While she is more aware of the technological side of the oil business than Lloyd, her emphasis is on the achievements of Standard's opponents like the Tidewater Pipe Line. There is no reference whatever to Rockefeller's support of Herman Frasch's experiments in the late 1880's with the heavily-sulfurated petroleum known as Lima-Indiana crude, experiments which represented the first large-scale application of chemical and engineering research to a refining problem in the United States. It was a gamble which could just as well have been a total loss and which no small firm could have risked, and while the outcome was highly profitable to Standard, the whole oil industry benefited as well—for one thing because in trying to find markets for the Indiana crude, Standard's engineers and salesmen succeeded in giving a vigorous boost to the use of oil as an industrial fuel.[16]

If I seem to have spent undue effort criticizing two admittedly outdated works, it is because these books and others like them had a pronounced influence on public opinion and public policy. The evidence marshaled by the authors pointed to the conclusion that big business was inherently bad. There is no suggestion, for example, that the nature of the refining operation gave the large-scale organization an advantage which unavoidably meant that the lesser firms could not hope to compete successfully, although this fact was brought out in a contemporary analysis of Standard Oil.[17]

The fact needs to be faced that it was the popular image of Standard Oil which was prosecuted and dissolved under the Sher-

man Anti-Trust Act, not the reality as it actually was in the early years of this century. Few people knew or cared what specific acts the company was charged with; Standard Oil had simply become the preeminent symbol of monopoly. Yet whatever prospect Standard had ever had of monopolizing the oil industry in the United States had disappeared irrevocably ten years before the Supreme Court's decree of dissolution—specifically, on January 10, 1901, when the gusher at Spindletop in Beaumont, Texas, started a new era in the history of the industry,[18] and the Spindletop achievement was primarily a technological triumph. It combined Anthony F. Lucas's informed guess about the domes on the East Texas coastal plain, based on his experience as a mining engineer, and the ingenuity of his drilling crew in devising new techniques to meet unfamiliar conditions.

The automobile industry provides another illustration of a growth pattern largely determined by technology. So far the disappearance of the lesser automobile manufacturers has been a source of regret to those who cherish the memory of the Pierce-Arrow and the Marmon rather than a cause of public and governmental indignation, but this situation could change. There is a definite suggestion of trust-busting crusade in the recent decision of the Supreme Court holding that the DuPont Company's stock ownership in General Motors was a violation of the Anti-Trust Laws.[19] The company was adjudged to have violated Section 7 of the Clayton Act forty years before, on the ground that its stock purchase might have restricted competition in selling paints and finishes to General Motors. The evidence that any such restriction occurred was not such as a historian would consider conclusive; the court, indeed, made such evidence irrelevant when it held that "The section (7 of the Clayton Act) is violated whether or not actual restraints or monopolies, or the substantial lessening of competition, have occurred or are intended." The fact that Du Pont, working in cooperation with Charles F. Kettering, was first in the field with the quick drying finishes which broke a serious bottleneck in automobile production seems to have carried no weight whatsoever.

I do not wish to suggest that the present organization of the industry is necessarily the best possible; we ought, however, to appreciate the fact that the prospect for the small producer became

gloomy as early as 1913, when Ford's moving assembly line went into full-scale operation. This was a superior production process, but it was feasible only for a big organization. To put it another way, the widespread ownership of automobiles which is a distinctive feature of American society has been made possible by a technology which can be most effectively employed in what the economists like to call "oligopoly." The manufacture of a car at a price within the reach of what Henry Ford referred to as "the multitudes" can be achieved only by mass production techniques. These require a tremendous investment in plant and equipment, and this investment in turn demands a high volume of sales. To cite a recent example, Ford Motor Company is reputed to have spent a quarter of a billion dollars in putting the Edsel on the market, with something less than unqualified success in spite of Ford's production and marketing facilities. If an established firm can encounter difficulty in introducing a new make of automobile, then the prospect of complete newcomer getting a foothold in a fiercely competitive market is remote, except in the unlikely event of a radical change in automotive technology which the established companies chose to disregard.[20]

The technology of production has also had a direct influence on the organizational structure of specific firms. Alfred D. Chandler, Jr. has pointed out that since 1900 the major innovations in the techniques of management and control have come in the industries most affected by the newer technologies, i. e., the application of chemistry and physics and the coming of electricity and the internal combustion engine.[21] To put it another way, the industrial processes which lend themselves most readily to diversification of product also stimulate decentralization of management.

In recent years there has been a considerable volume of scholarly work in industrial history in which technology has been given its proper weight, but much more needs to be done. Apart from the numerous other areas of economic activity which could use similar studies,[22] there are some general problems on which we have barely scratched the surface. For example, such research as has been done on innovation indicates that while the technology of production generally favors the large firm, significant innovations are more likely to originate in the small ones,[23] but we need to know much more than we do about the process of innovation. We cannot yet

make adequate comparisons of situations in which technological developments have come in response to immediate economic pressures with those in which a technological advance has stimulated a new industrial growth. In addition, it cannot be said that the recent work in industrial and technological history has as yet appreciably made its way into the main stream of historical thought.

Historians of American technology have therefore a dual task to perform: first, to write the history of the technology itself; second, to have their findings incorporated into the total picture of American life. The attempt is worth making. We can all agree that science and technology occupy a vital place in our present-day civilization; we will agree equally that their importance is likely to increase in the future, unless they prevent us from having a future. A more thorough and accurate understanding of how they have influenced and been influenced by the American environment is a desirable step toward an intelligent appreciation of what they may hold for us now.

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[5] C. McL. Greene, *Eli Whitney and the Birth of American Technology* (Boston, 1956), pp. 101-102.

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[7] See Nathan Appleton, *The Introduction of the Power Loom and the Origin of Lowell* (Lowell, Mass., 1858).

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[11] Alfred Cowles, *The True Story of Aluminum* (Chicago, 1958), pp. 7, 8.

[12] *Ibid.*, p. 47.

[13] Henry D. Lloyd, *Wealth Against Commonwealth* (New York, 1894), p. 44.

[14] Ida M. Tarbell, *History of the Standard Oil Company* (New York, 1904), Vol. I, p. 42.

[15] Allan Nevins, *Study in Power* (New York, 1953), Vol. I, p. 42.

[16] This episode is described in R. W. and M. E. Hidy, *Pioneering in Big Business* (New York, 1955), pp. 165-168.

[17] G. H. Montague, *Rise and Progress of the Standard Oil Company* (New York 1903), p. 8.

[18] J. A. Clarke and M. T. Halbouty, *Spindletop* (New York, 1952) is an accurate if highly dramatized account of this event.

[19] 353 *U. S.*, 586 (June 3, 1957).

[20] I am referring here to production for the mass market. The manufacture of specialized vehicles is another matter altogether.

[21] A. D. Chandler, Jr., "The Beginnings of 'Big Business' in American Industry," *Business History Review*, XXXIII, 1 (Spring, 1959), p. 25. See also his "Management Decentralization; An Historical Analysis," *ibid.*, XXI, 2 (June, 1956), pp. 115 ff.

[22] Agriculture, iron and steel, mining, food processing, and the use of electric power in the 20th century are conspicuous fields to which this statement applies.

[23] The best studies of this phenomenon are W. R. MacLaurin, *Invention and Innovation in the Radio Industry* (New York, 1949); Harold C. Passer, *The Electrical Manufacturers, 1875-1900* (Cambridge, Mass., 1953); W. Paul Strassman, *Risk and Technological Innovation* (Ithaca, N. Y., 1959); and John Jewkes, David Sawers, and Richard Stillerman, *The Sources of Invention* (London and New York, 1958).